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(54) **Radar Systems**

(57) In a radar system, a high resolution waveform is used in which returns from a series of pulses are processed together by integration in order to obtain high resolution values of range and frequency shift of a target such as an aircraft 24. The range cell is sufficiently small that a range profile of the target is built up, and the frequency processing is also high resolution, and this enables a range frequency matrix to be built up, which can be compared, (25 Fig 3) with matrices of known targets, (24 Fig 3), in order to improve the chances of successfully identifying a target. A coarse/fine target resolution system is used (Figs 2, 3).

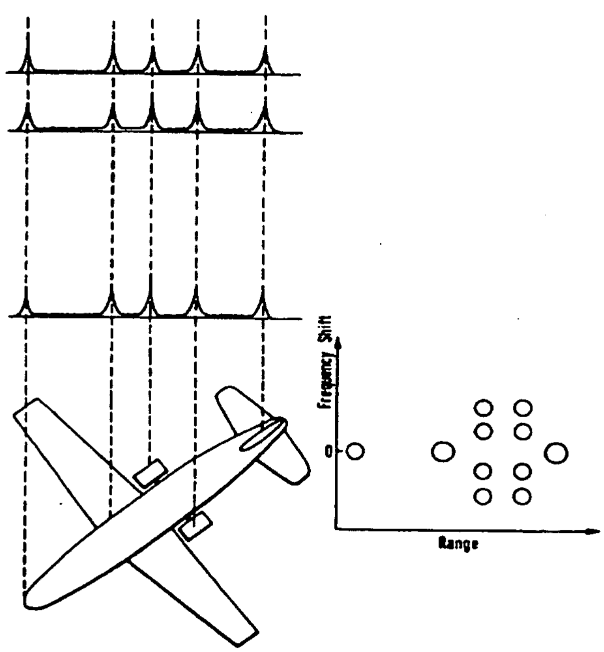

FIG.6

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG.1

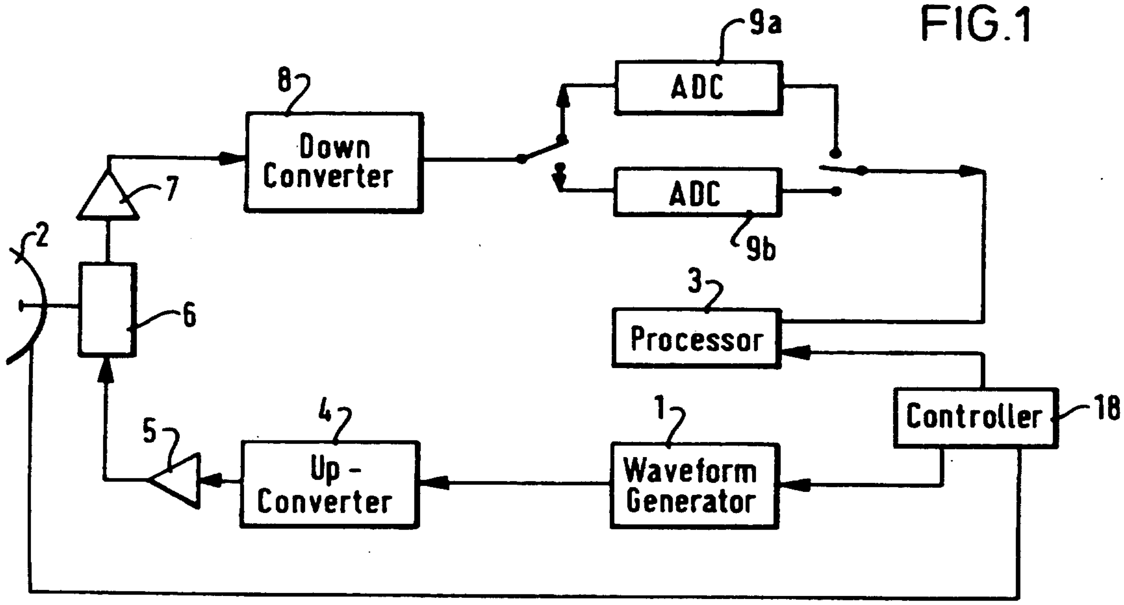
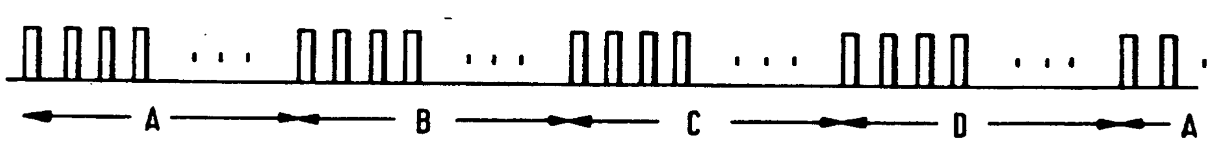


FIG.4



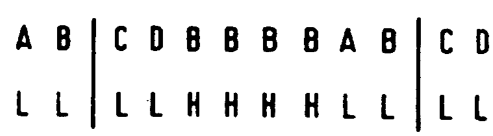
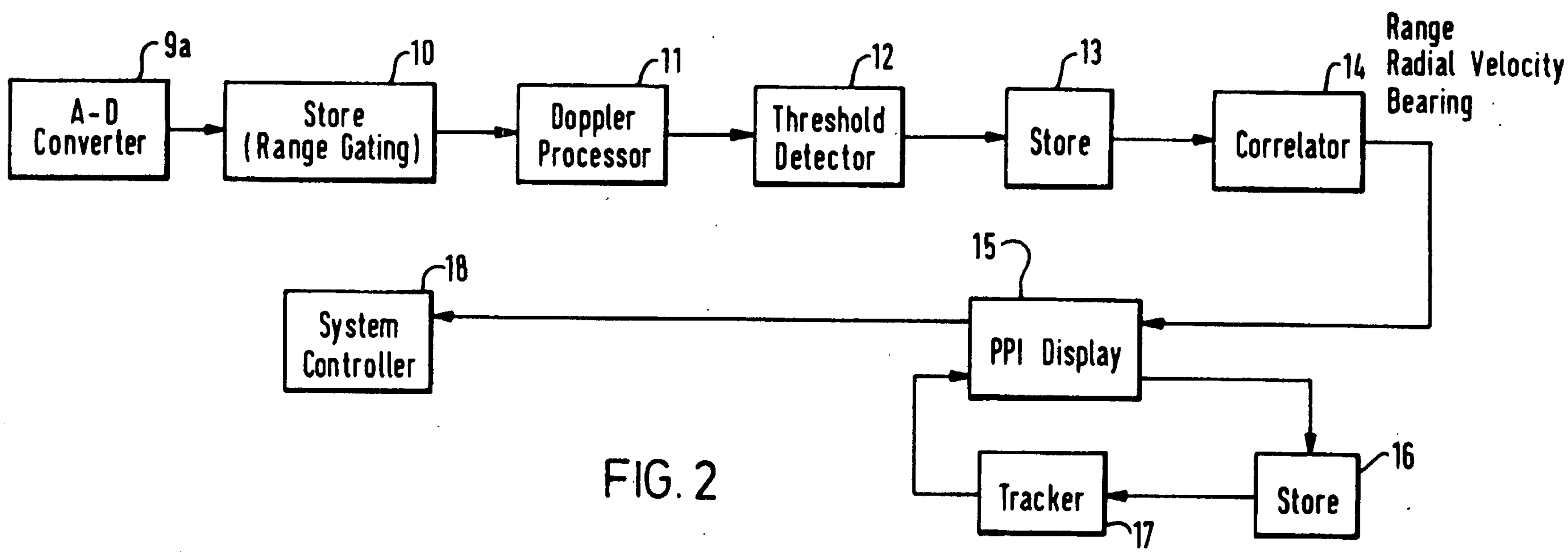
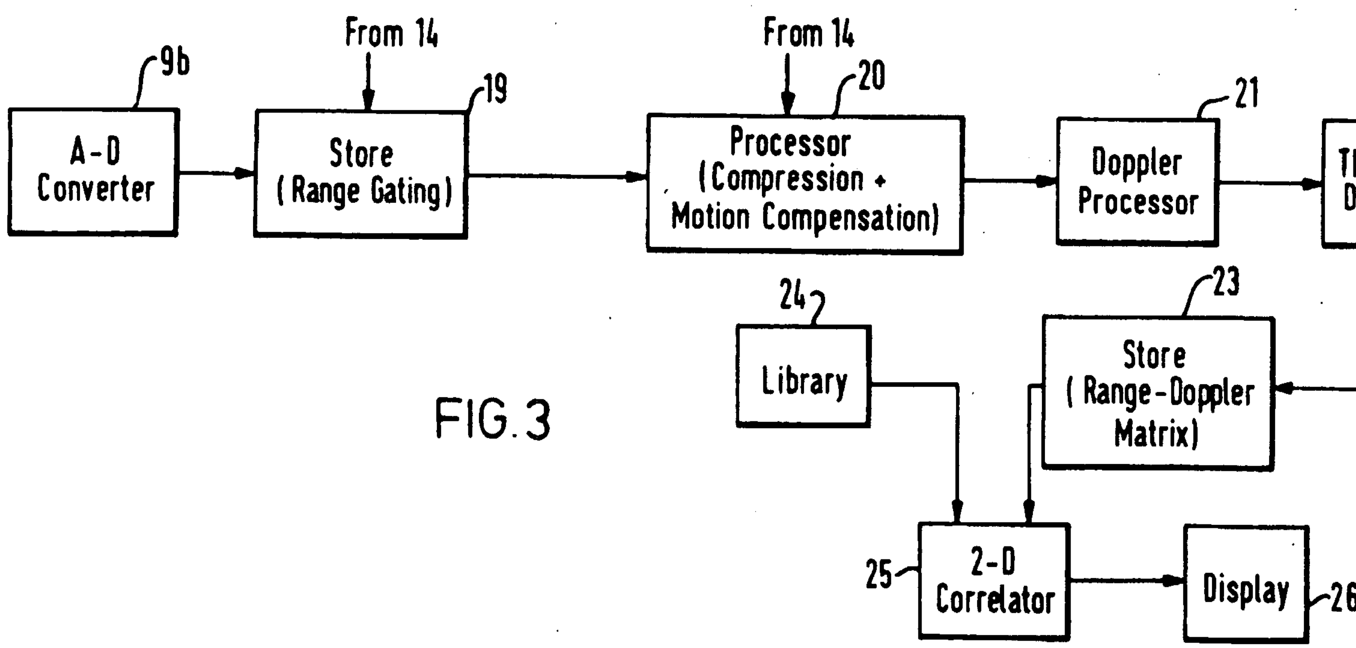


FIG.5



A-D Converter
9a
Store (Range Gating)
10
Doppler Processor
11
Threshold Detector
12
Store
13
Correlator
14
Range
Radial Velocity
Bearing
PPI Display
15
Store
16
Tracker
17
System Controller
18

FIG. 2



A-D Converter
9b
From 14
Store (Range Gating)
19
From 14
Processor (Compression + Motion Compensation)
20
Doppler Processor
21
Threshold Detector
22
Store (Range-Doppler Matrix)
23
Library
24
2-D Correlator
25
Display
26

FIG. 3

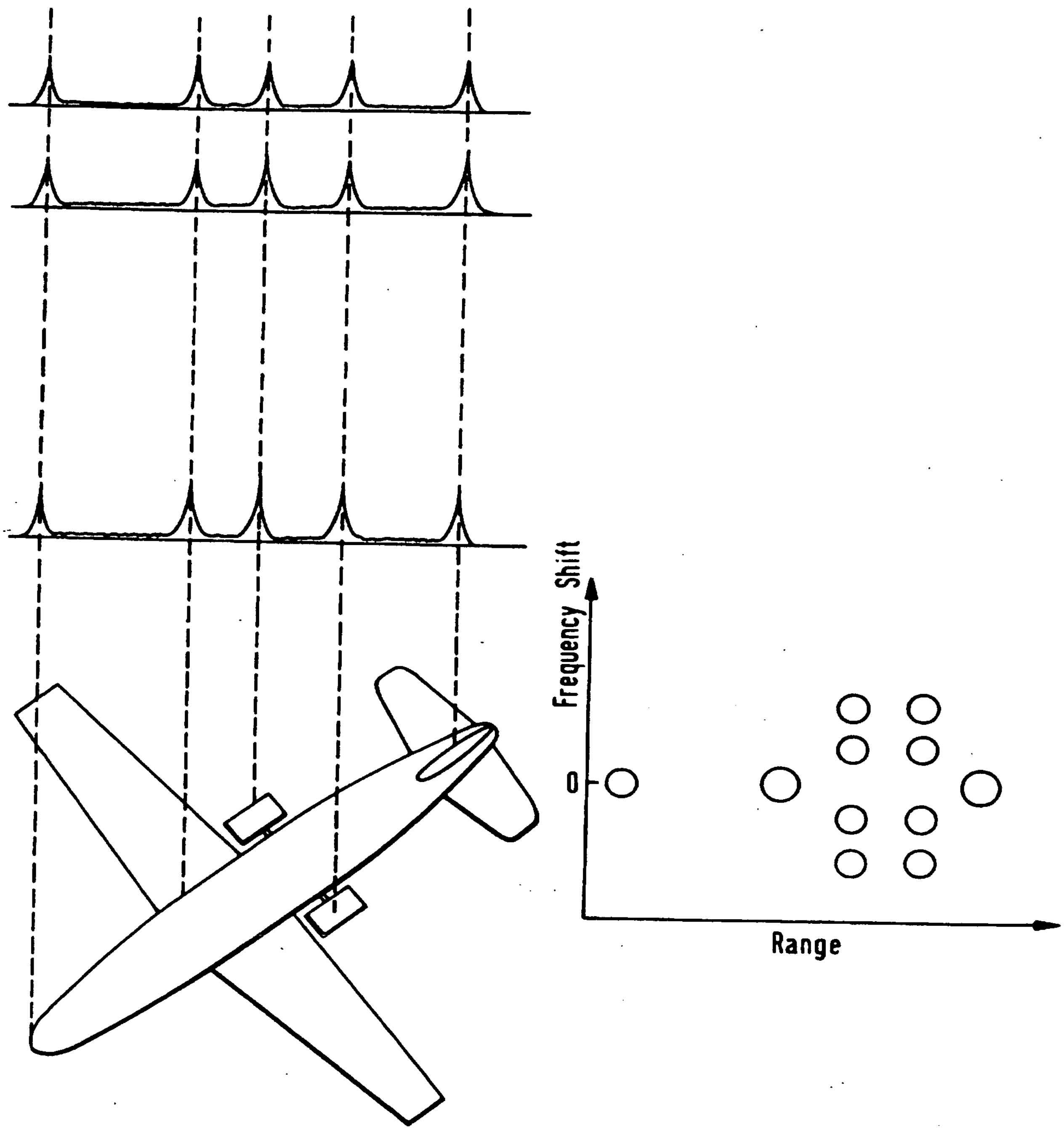


FIG.6

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Radar System

This invention relates to radar systems, especially surveillance radar systems.

In such systems, a region of space may be repeatedly scanned by a transmitting beam of radar pulses and by a receiving beam to receive the echo signal returns.

In order to not just detect the presence or absence of a target, but to actually obtain a signature for the target from which it can be recognised, it has been proposed to scan a target with a high resolution waveform with a small range cell and to obtain a range profile of the target such that different parts of the target can be separately identified. It has also been proposed to process radar returns to obtain a frequency shift profile of the target whereby different parts of the target can have different frequency shifts eg in an aircraft the engines would produce different frequency shifts to that produced for the skin of the aircraft.

The invention provides a radar system, comprising

means for transmitting an electro-magnetic waveform and receiving radar return echo signals, and means for processing the groups of echo signals in such a way that respective frequency shifts are associated with the portions of the echo signals corresponding to different regions of a target.

The association of the frequency shift profile information with the respective portions of the range profile information increases the possibility of being able to identify the target.

The range-frequency matrix may be compared with those for known targets in order to identify the target detected.

A dual mode radar system constructed in accordance with the invention will now be described, by way of example, with reference to the accompanying drawing in which:

Figure 1 is a block diagram of the radar system;

Figure 2 is a block diagram of the configuration of the processor when operating in a low resolution

mode;

Figure 3 is a block diagram of the configuration of the processor when operating in a high resolution mode;

Figure 4 is a schematic diagram of a typical pulse train transmitted in the low resolution mode;

Figure 5 indicates in symbolic form a typical waveform pattern transmitted in the vicinity of a target; and

Figure 6 indicates in schematic form the relation between the radar returns, target and range frequency matrix.

Referring to Figure 1, the radar system is mounted on an aircraft so as to be downward looking, and comprises a waveform generator 1 capable of transmitting either high or low resolution waveforms from an antenna 2, and a processor 3 for processing the radar returns. The antenna repeatedly scans a region of interest eg a sector of 120°, although it could scan over 360° if desired.

The waveform selected is mixed with a suitable oscillator frequency to convert it to radio frequency at the frequency converter 4, amplified at amplifier 5 and fed to antenna 1 by duplexer 6. Radar echoes received at the antenna 2 are fed by duplexer 6 to low noise amplifier 7, and are down-converted to baseband at frequency converter 8. This signal is digitised at analogue-to-digital converter 9a, 9b, depending on whether a low or high resolution waveform is being transmitted, and the samples are processed in processor 3. The entire radar system is under the control of controller 18.

In a first mode, a low resolution waveform consisting of 2 microsecond pulses of an unmodulated carrier (eg 10 GHz) are transmitted. Referring to Figure 4, 50 pulses are transmitted at each of the four different pulse repetition frequencies (p.r.fs) A-D in turn eg four p.r.fs between 19 and 21 kHz. The number of pulses and the p.r.f are chosen so that with a typical angle of receiving beam of 2° to 3°, and a typical scan rate of around one second for a cycle of the antenna, all four p.r.fs are pulsed through twice while the receiving beam views a target.

Referring to Figure 2, the in-phase and quadrature channels of the radar returns are sampled at 500 kHz producing around 24 samples after each transmitted pulse, corresponding to a range cell of 300 metres. These samples are stored after digitisation in range gate bins in store 10. Doppler processor 11 takes the last 200 samples stored in range gate store 10, corresponding to the first range gate, and processes them to obtain Doppler shift and hence radial velocity of any target appearing in range gate 1. This is sequentially repeated for the over 24 samples. The results are thresholded in threshold detector 12 and stored in store 13, after which correlator 14 resolves ambiguities in range and radial velocity.

It will be appreciated that the pulse train A will be ambiguous both in range (the reflection of a pulse from a target will not appear before the next pulse but after the next pulse or perhaps after the next two or more pulses), and in Doppler shift (which will be higher than the p.r.f), but by use of four or more pulse trains of different p.r.fs, these ambiguities can be resolved in a known manner.

Display 15 (eg PPI display) is thus fed range and velocity information corresponding to targets in the region of the scan together with relevant bearings, and tracker 16 calculates the position the targets will occupy on the next scan on the basis of the information stcred on the previous scans of the target in store 17.

In the course of a single scan, the cycle of four p.r.fs will be repeated hundreds of times, and is possible to track many targets simultaneously. A higher resolution waveform is transmitted in the vicinity of each target, and the range and radial velocity data is used in the processing of the radar returns from the higher resolution waveform.

For the higher resolution waveform, modulated pulses of bandwidth 400 MHz are transmitted, and the radar returns are sampled, in-phase and quadrature channels at 400 MHz, corresponding to a range cell of 0.375 metres. However, the same pulse width (2 microseconds) is used and one of the same four p.r.fs A-D is used. The p.r.f used is that determined by correlator 14 to be the best from the point of view of blind ranges and blind radial velocities. Blind ranges occur if the target is at such a distance that the radar

returns from a transmitted pulse reached the antenna at the same time as the next, or any subsequent, pulse is being transmitted. Blind radial velocities occur if the Doppler shift is coincident with a multiple of the p.r.f. Another problem which could make a p.r.f unsuitable is clutter. This is mainly caused by reflections from the ground. Again, the correlator 14 selects a p.r.f for which the return from the ground (which will appear after a number of subsequent pulses, does not coincide with the return from the target, which will likewise occur after a number of transmitted pulses). Hence the controller 18 interrogates the correlator 14 in the case of a target detection, to select the p.r.f out of A-D for which the return from the target is not obscured by clutter, and is not at a blind range or blind radial velocity.

Having detected a target on two successive scans, and estimated its position for the third scan, referring to Figure 5, as the target enters the beam (between the vertical lines) the lower resolution waveform is continued as before to confirm the target is in its expected position. Then the selected p.r.f (say B) is transmitted for four cycles of 50 pulses each with the high resolution modulated waveform. For better accuracy

the rate of scan over this period can be reduced eg halved and the number of pulses transmitted may be increased (eg 400 instead of 200). The normal pattern of p.r.fs A-D is thereafter reverted to, and the normal antenna scan speed is reverted to, in order that ESM (Electronic Surveillance Measures) on a target aircraft would be unlikely to detect that the higher resolution mode had been used, especially since the same pulse width is being maintained. The scan then continues in the lower resolution tracking mode until another target is detected.

Referring to Figure 3, in the higher resolution mode, higher resolution analogue-to-digital converter 9b is used, and the samples are stored in range gate (cell) order in store 19. However, there are around a thousand range cells in the higher resolution mode corresponding to one range cell in the lower resolution mode, and hence only those range samples are stored which correspond to the expected range of the target and, for this reason, the store 19 has an input from the correlator 14 in Figure 2.

In the usual way, the samples of the pulse returns must be compressed to yield the high resolution

available from the modulated transmitted waveform. Unlike the lower resolution waveform, with the higher resolution waveform and its smaller range cells, a large number of pulse returns (over 100) are processed together by integrating them to restore the signal to noise level to approximately the same level as that achieved with the lower resolution waveform. However, the range cells are now so small that a target such as an aircraft, which could approach or recede at several hundred metres a second, could well be in different range cells while it is in the beam. To take an extreme example which is very unlikely to happen in practice, a point target could be such that it would appear in one range gate after one pulse, in the next range gate after the next pulse, in the next range gate after the next pulse, and so on. Obviously this range walk effect must be compensated for before range processing, but this can only be done if the radial velocity is known. Hence processor 20 has an input for a signal from correlator 14 by means of which the velocity information is fed in. It turns out to be convenient to perform range compression at the same time as motion compensation in the processor 20, but these operations could be carried out as two separate stages if desired.

The processor 20 thus yields high range resolution information concerning a target. Since the range cell is 0.375 metres, a range profile is built up concerning the target.

In the same way as in the low resolution mode, the samples from corresponding range cells (compensated for range walk) for a number of successive pulses, are Doppler processed in 21 to yield a high resolution value of the radial velocity for the target. The results are thresholded in threshold detector 22.

Once again, the frequency shift measurement is high resolution so a profile of a object is obtained in the case where different parts of the object have different frequency shifts eg for an aircraft the skin will produce a Doppler shift appropriate to the radial velocity, whereas the turbine blades and the engines will produce different frequency shifts.

The calculation of frequency shifts is carried out for each range gate in the vicinity of the target, and a target such as an aircraft will occupy several range gates. Thus, a two dimensional matrix will be built up in the store 23. Referring to Figure 6, a number of

successive radar returns have been schematically illustrated one underneath each other, corresponding to a target in the form of an aircraft 24. The nose, roots of the wings, and tailplane, all have a Doppler shift corresponding to that of the skin and can be plotted on the range frequency matrix 25 at the same value of frequency shift. The engines however will have a characteristic frequency specturm, and will be represented in the matrix by respective positions at the same range as the base of the wing tips for the illustrated aircraft, but with different frequency shifts.

This information in store 23 is compared with information on known aircraft in library 24 by means of a two dimensional correlator 25, and display 26 lists the possible choices which the target could represent, with relevant probabilities.

Of course, variations may be made without departing from the scope of the invention. Thus, the higher resolution mode processing could simply use range and velocity of target as obtained from a previous scan, rather than using values which are estimated for the new scan. Also, rather than perform high resolution

processing in the vicinity of the estimated position of the target (which could be part way through a low resolution range cell), the higher resolution process could be carried out for a discrete number of low resolution range cells. Instead of four low resolution p.r.fs more eg eight could be provided per cycle. Equally, instead of steady scans with optional increased dwells for targets, low resolution scans at constant speed could be alternated where necessary with high resolution scans at the same or a slower speed. Also, while the configuration of the processor has been illustrated by different components in Figures 2 and 3, all these processes could be carried out in one processor under the control of suitable software.

CLAIMS

1. A radar system comprising means for transmitting an electro-magnetic waveform and receiving radar return echo signals, and means for processing groups of echo signals in such a way that respective frequency shifts are associated with portions of the echo signal corresponding to different regions of the target.

2. A radar system as claimed in claim 1, in which the frequency shifts for the different regions of a target are compared with those for known targets.

3. A radar system as claimed in claim 1 or claim 2, in which the waveform is such as to give a resolution within the range of 0.2 metres to 2 metres.

4. A radar system as claimed in claim 3, in which the waveform is a pulse modulated waveform.

5. A radar system substantially as herein described with reference to the accompanying drawings.

Amendments to the claims have been filed as follows

1. A radar system comprising means for transmitting an electro-magnetic waveform and receiving radar returns, and means for processing the radar returns to determine the frequency shift associated with, as well as the range of, individual parts of a target, in order to permit target identification.

2. A radar system as claimed in claim 1, in which the frequency shifts for the different parts of a target are compared with those for known targets.

3. A radar system as claimed in claim 1 or claim 2, in which the waveform is such as to give a range resolution within the range of 0.2 metres to 2 metres.

4. A radar system as claimed in claim 3, in which the waveform is a pulse modulated waveform.

5. A radar system substantially as herein described with reference to Figure 6 of the accompanying drawings.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9004458

Relevant Technical fields

(i) UK Cl (Edition K) H4D: DRPQ, DRPS, DRPU, DRPV, DSPD, DSPJ, DRPF

(ii) Int Cl (Edition 5) G01S

Search Examiner G A McLEAN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES WPI; CLAIMS

Date of Search 7 AUGUST 1990

Documents considered relevant following a search in respect of claims 1 - 5

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 1,554,864 A (SECRETARY) - whole document	1 - 4
X	US 4,603,331 (USA) - whole document	"

SF2(p)

Category	Identity of document and relevant passages	Relevant to claim(s)

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